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ABSTRACT OF "DYNAMIC OCEANOLOGY" BY N. N. ZUBOV

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Author's Foreword

Oceanology is a young and unestablished science and there is still much disputed material in it. Our oceanological literature, other than purely descriptive works, is unusually poor. I approach this science not only as a scientist but also as a practical worker. I bring to oceanology my experience as commander of a military vessel, as a pilot, as a hydrographer, as an Arctic explorer. Dynamic Oceanology was written to familiarize scientists, students, and practical workers with my views, as drawn from voyages, work in the sea, and flights over the sea. It should also indicate the progress of oceanology throughout the world and point out methods for its development.

Dynamic Oceanology, like my books Sea Waters and Ices and Ice of the Arctic, is neither a textbook nor a monograph. Some of the material was drawn from the course in oceanology which I taught for more than 10 years in the Moscow Hydrometeorological Institute.

In writing this book, I was confronted with difficulties in determining which problems should be emphasized. I am convinced that there is no place in a book such as mine for the description of any type of instruments, methods of observation, and processing of data. In my book the mathematics has been considerably abridged and simplified, but possibly more could have been done in this line. This especially refers to the chapter "Sea Currents," in which the solution of the equations of motion is given in excessive detail.

The problem of classification of phenomena and of terminology was also an important one in writing the book. These problems undoubtedly should be solved at conferences and in commissions. These solutions, however, may be long forthcoming, though it is clear that the existing terminology is quite unsatisfactory for the present degree of development of oceanology, and blocks the development of oceanology as a science. Therefore, making use of the fact that my book is neither textbook nor manual, I have made a courageous statement of my ideas.

As was already mentioned, the book was based partially on lectures which I gave at the Moscow Hydrometeorological Institute, but the organization of the State Oceanographic Institute, of which I was placed in charge, undoubtedly served as the impetus for the book's completion. The establishment of this institute, which should become the center of oceanographic science in our country, has already provoked great interest in oceanographic science. This interest will undoubtedly grow, as is reflected in the expansion of scientific-research centers at the separate seas and of the Central Research Institute. This increased interest in oceanographic science will also aid in the development of our national economy on the seas. The merchant marine, and the fish and chemical industries will submit increasingly difficult problems to oceanographic science; these problems cannot be satisfied thoroughly unless their solutions are based on a sound theoretical and experimental foundation.

I am indebted to many persons for their aid in writing this book, but especially to A. D. Dobrovol'skiy, my assistant in the Chair of Oceanology of the Hydrometeorological Institute. I also wish to thank M. M. Vaynberg, F. L. Mozeson, K. M. Sirotov, and L. F. Rudovits for important corrections. V. M. Komisarova rendered invaluable technical assistance.

Conclusion

Dynamic oceanology as an independent science was founded very recently, although certain of its divisions, such as tidal phenomena, for example, were studied long ago by Newton, Laplace, and Eri, while the theory of the trochoidal waves is credited to Gerstner.

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Dynamic oceanology was not developed in all its branches, however, until the 1900s, after the works of Bjerknes, who established the theory of density currents; Nansen and Ekman, who created the theory of wind and drift currents; Shmidt, who established the theory of vertical mixing; and other researchers, who generalized and extended these theories.

Generalized works on oceanography which included problems of dynamic oceanology began to appear only at the beginning of this century. Of these works, we should mention Krummel's Oceanography, Shokal'skiy's Oceanography, Defant's Dynamic Oceanography, Berezkin's Dynamics of the Sea, and Sverdrup, Fleming, and Johnson's Oceans.

In view of the fact that the science is so young, it is not surprising to note the increasing number of articles appearing in the scientific periodicals of all nations either treating problems previously set up by the founders of dynamic oceanology or setting up new problems. These new problems arise in connection with the production of better observations in nature or follow from the development of related sciences, primarily hydrodynamics, thermodynamics, and physics.

Although dynamic oceanology in its development has been and is being supported by hydrodynamics, thermodynamics, and physics, it still is a branch of natural science, and not a branch of the sciences listed above. This principle guided me in writing my book, and I therefore deliberately omitted theories and solutions of problems which were more concerned with mathematical exercises than the solution of problems presented by nature.

In the foreword, I mentioned the difficulties which arise in writing a book in connection with problems of terminology and classification of phenomena. Although I attempted wherever possible to introduce clarity and definition into these problems, I must acknowledge that I have not coped fully with this problem. Although these problems look easy at first glance, they actually demand the most careful attention. For example, a special commission of highly qualified specialists was created in the State Oceanographic Institute to develop a classification for sea currents. This commission worked out the problem from all standpoints, and yet its classification could be criticized severely. This is lamentable, since good classification greatly facilitates the theoretical and experimental development of any natural-science problem.

I consider the problem of constants to be the one most deserving of rapid solution. The natural constants which have been determined with sufficient accuracy for dynamic oceanology are the dependences of the density of sea water upon the temperature, salinity, and pressure, obtained from the works of Knudsen, Ekman, and Bjerknes. Unfortunately, even now, no accurate determination exists for such an important constant for dynamic oceanology as the coefficient of turbulent viscosity, even for a homogeneous liquid. To simplify calculations, it is usually assumed that this coefficient does not change with depth and, in any case, does not depend upon the velocity gradient. At the same time, the speed of mixing undoubtedly depends upon the velocity gradient and also, in a nonhomogeneous liquid, upon the stability of the layers or upon the density gradient. Because of considerations stated in the foreword, problems of the dynamics of sea ices were discussed little in this book, but we can note that the determination of constants for sea ices, in particular the constants for the mechanical properties of ice, by individual researchers differ greatly and this makes their practical utilization difficult.

But if the physical constants used in dynamic oceanology have not been determined with sufficient accuracy, the oceanological constants are practically undetermined. We introduce several examples to clarify this statement: At what wind speed on a calm surface of a homogeneous sea will capillary waves appear? What vertical density gradient limits vertical friction mixing created by a given velocity gradient? What vertical gradients of temperature, salinity, and density determine the layer of sudden change of these characteristics?

In connection with determining oceanological constants, the problem of determining the time necessary to complete various processes is most important. Thus, it is exceedingly important to know, for example, with what speed under equal conditions vertical friction and convective mixings are propagated, by how much the vertical and horizontal friction mixings differ in speed of propagation, and finally, how much mixing is accelerated if convective mixing acts simultaneously with vertical friction mixing.

It has now been established that molecular mixing is of little importance in the ocean and that the primary roles belong to friction and convective mixing. But we know almost nothing about nor can we express the degree of importance of, biological mixing: the latter, however, undoubtedly has an important role, especially in the coastal regions.

Myriads of living organisms constantly move in various directions at various speeds both in the body of the ocean's waters and along its bottom. At the same time, all organisms, plant and animal, actively and passively floating, attached or unattached to the bottom of the ocean, constantly draw from its waters life-giving chemical elements and compounds. In certain organisms, elements are found which are soluble in sea water in such negligible amounts that their presence in the sea water itself cannot be detected by even the most refined contemporary analyses. These elements include cobalt, nickel, and tin, which have been found in the blood of certain holothurioidea, lobsters, oysters, mollusks, etc. What amounts of water, then, must pass through the body of the individual organisms in order for them to selectively absorb the substance needed by them?

Other organisms, passing through the water and isolating the elements which they need, simultaneously coagulate the suspensions always found in ocean waters, thus purifying its waters and accelerating sedimentation processes. According to certain calculations, one average medusa passes up to one liter of water through its body in an hour. If to the coagulation activity of organisms we add the coagulation of colloids and the amount of suspensions created by the combination of oppositely charged ions of the shore mud and the sea water, then we understand why the coastal waters are so markedly different from the main waters of the given sea in color and transparency. This problem is closely linked with shore discharge, with the wave activity of the sea, and, in particular, with the wave agitation of the ocean.

The unrest of the ocean is a new concept, but nonetheless it can be classified, if only approximately. Let us consider two regions of the ocean with tides equal in magnitude; in the first the tides are semidiurnal, while in the second they are diurnal. It is clear that tidal unrest in the first will be twice that in the second. We can also compare the separate regions of the ocean with respect to their wave unrest. It is immediately apparent that the regions of the ocean situated near extremities of dry land pushed far out in the ocean, such as the Cape of Good Hope, Cape Horn, Cape Nordkap, etc., to which the waves and swells approach from various basins, are characterized by high wave unrest.

Further, we can visualize unrest of the ocean created by pulsations of sea currents with respect to speed, direction, and lateral displacement. For example, it has been proven that Nordkap current is displaced first to the north, then to the south. The oceanological regime changes very sharply at the southern and northern limits during these displacements. The same may be said of the oceanological regime of the coastal regions undergoing clearly expressed breeze and monsoon phenomena. Thus, we may speak of breeze and monsoon unrest, which can, however, be included in the more general concept of the driving-in and driving-off unrest of the ocean.

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The problem of the contact layer, which is the layer of a sudden change in temperature, salinity, or density, is a very important one in connection with sea currents, no matter what their origin or character.

The contact layer is created by the velocity gradient and may be horizontal, inclined, or even vertical, as, for example, along the lines of convergence of sea currents moving in different directions. When this layer is horizontal, it is manifested in internal waves. When it is vertical, we can observe it in form of rip tides. We may ask what are the horizontal velocity gradients which create, for example, a rip tide, a phenomenom which sometimes surprisingly occurs in calm air?

The unrest of the ocean due to the unrest of the atmosphere is most important both for coastal and for open regions of the ocean. For example, regions characterized by high unrest of the atmosphere are also regions of increased cyclone activity. When a cyclone passes through a given point of the sea, the atmospheric pressure is not only changed rapidly back and forth at this point, but the wind velocity also changes rapidly, thus changing the direction, magnitude, speed, etc., of the waves and currents developed by this wind. Changes in wind velocity also change weather conditions. The air temperature and humidity change correspondingly, thus changing the temperature and salinity of the upper layers of the ocean. All this ultimately affects the mixings, friction and convective, of the upper layers of the ocean. In this process, it is important to distinguish: (1) the duration of the separate cycles of weather conditions and (2) the frequency of the change of cycles. The shorter the separate cycles, the thinner the layer of unrest, and vice versa.

The problem of unrest of the ocean has for the present only been posed, but it deserves the most careful attention, the more so in that it is very closely linked with the problem of water masses.

The next problem deserving of more thorough study is the problem of wave phenomena. Classification is necessary in this problem as in no other. Many efforts have been made in this direction. In particular, a classification for wind waves according to their periods was devised very recently in the State Oceanographic Institute, but this problem is still far from completion.

Furthermore, a new theory of the emergence of wind waves was created comparatively recently, also in the State Oceanographic Institute. But there are still many almost untouched problems concerning wind waves alone. First of all, Dynamic Oceanology, with a few exceptions, is devoted to problems on the form of waves, but not to problems concerning their gradual development and dying away. For example, no theory explains satisfactorily how a wave several centimeters in length gradually intensifies and develops into a wave several hundred meters long.

The problem of the formation and development of wind waves when pressure systems pass through a given point of the sea, when the wind direction and force changes in accordance with a definite law and correspondingly changes the elements of wind waves, is very important and most completely untouched.

Finally, the practically important problem of the action of a developed wind wave on a shore and on port constructions, and also problems concerning the destruction and creation of regular two-dimensional short and long waves, are almost untouched from the physicomathematical standpoint.

In tidal phenomena, the leading problem is the problem of the horizontal and vertical orbits of water particles. A new concept of progressive-standing tidal waves was introduced very recently in the State Oceanographic Institute. This concept arose in processing the extensive observations made by expeditions of the institute in the open regions of the neck of the White Sea. In passing, this example showed the results which can be obtained if the same problem is studied simultaneously by theoretical experiment in the laboratory and observations in nature.

Turning to sea currents, we note that the basic difficulty in the future development of this problem is the fact that the equations of hydrodynamics deal with laminar motion, while any motion in nature is turbulent. Further, there still is some question as to whether dissipative members should not be introduced into the equations of motion.

In any case, Ekman's theory of wind currents produces such great conflicts in the equatorial zone that it undoubtedly must be checked by experiment and observations. For this purpose, a suitable region of calm sea must be selected, the proper equipment must be used, and the proper methods of processing the data must be developed.

The next problem awaiting development and clarification is the problem of the connection of the pressure map and sea currents and, in particular, the problem of sea currents created by moving pressure systems. Up to the present, we have worked mainly upon the dependence of sea currents upon the wind. But, in many cases, it is more convenient and simpler to establish the dependence of sea currents upon the pressure map even if only because the wind is, at the shores in particular, very much subject to local conditions and therefore not always sufficiently representative. In a very crude fashion, I have attempted to do something with respect to the influence of moving pressure systems on the movement of ice and on the position of the ocean level, but this problem should be approached with more refined mathematical tools.

We should further focus attention on monsoon phenomena in ocean waters both at its open shores and, in particular, in its almost enclosed basins. In the summer, the coastal waters are heated and distilled more than open waters. In the winter, the coastal waters are cooled more, and, moreover, made more saline (in ice formation). A unique monsoon circulation therefore arises in the waters of each basin. The same considerations may be applied to breeze phenomena. Theoretical development of these problems is extremely desirable.

A very important problem has recently been put forward in connection with the observations of Langmuir and Woodcock, namely, the problem concerning the structure of the upper layers of wind currents: Are the eddies with horizontal axes parallel to the wind purely dynamic or thermodynamic phenomena, and what is the role of the Coriolis force in creating the asymmetry of these eddies? Few observations have been made on this problem, and theoretical studies have not even begun.

The next group of problems of dynamic oceanology awaiting clarification and solution are the problems connected with the ocean level. First of all, the very concept of the ocean level, or more accurately, the average ocean level in tidal and tideless seas and the concept of the so-called null depth are far from established and are understood differently in different countries. Nonetheless, the basic problem remains that of aperiodic variations of the level. Studies of these variations of the level are of prime importance to the national economy, and these variations are most closely connected with the passing of pressure systems over a given region.

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The problem of the transfer of wind energy to water masses and the absorption of this energy in the water masses touches upon problems of wave phenomena, wind currents, and wind variations of the level.

The development of the study of water masses is very important. The concept of a water mass is closely connected with four basic processes in the ocean: physical, chemical, geological, and biological. This concept must include such problems as the genesis of water masses, their formation, transformation, stability, etc. All water masses basically are formed on the surface on the ocean and then gradually fill the ocean to its deepest recessions. But time is necessary in order that the water masses which are created on the surface of the ocean, mainly in the Arctic regions, can move down to the depths and intersect in certain regions of the equator. Thus arises the problem of the age of water masses.

Thus far we have learned to determine the age of water masses by one characteristic alone, namely, by the oxygen deficiency, or, more accurately, by oxygen waves. In certain areas, this age may be judged by temperature waves. Other characteristics must be sought, and in searching for these characteristics, a better oriented study of biochemical processes probably can be of assistance. Finally, the problem of the general circulation of the ocean is a most important one in connection with all basic branches of oceanology. The contemporary theory divides this general circulation into a number of local circulations, and the subdivision of the World Ocean according to these circulations is now one of the most prominent problems of dynamic oceanology.

This problem is closely connected with problems of mixing and transfer of water masses by sea currents. In the final analysis, this problem will be solved in the solution of the very important and still only guessed at problem of natural science, namely, the problem of the constancy of the salt component of the waters of the World Ocean. Actually, despite the extreme diversity of the physical, chemical, biological, and geological processes and the conditions under which these processes take place, sea water represents something of a single solution of certain basic elements. In some regions of the ocean, this solution is more dilute, and in other regions, less dilute. In some regions, certain second-degree elements are temporarily or permanently present, but always in such negligible amounts that their presence is in no way reflected in the density of sea waters or in their movements. There is no doubt that such singularity of the waters of the World Ocean is partially due to the great mobility of water, and this should be remembered in studying ocean dynamics.

I hope that practical workers, port constructors, shipbuilders, ship captains, workers in the fishing industry, and others, will make use of this book. It will help them to understand processes occurring in the sea and thereby enable them to submit problems concerning this science and utilize the resultant data. I can hope for this because all my theoretical concepts are based on direct practical requirements.

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